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GIN TRASH COLLECTION EFFICIENCY OF SMALL-DIAMETER CYCLONES

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INTRODUCTION

The collection of gin trash at cotton gins has become important in recent years. Because of today's mechanized harvesting methods and accelerated harvesting and ginning rates, present day cotton gins are required to handle literally tons of gin trash each ginning day. During the 8- to 10-week ginning season, modern ginning plants handle from 1 to 10 tons of trash per hour.

Practically all gin trash is handled by pneumatic conveying systems employing centrifugal fans and closed pipes. These systems, depending upon the size of the gin, utilize from 20,000 to 40,000 cubic feet of air per minute. A trash collection system must remove the gin trash from this large volume of air and do so efficiently and without interrupting the normal ginning process.

To date, the most successful device used to remove gin trash from the conveying air is the small-diameter cyclone collector. Large-diameter cyclones have been used in the past, but in recent years most of these have been replaced by the more effective and less costly small-diameter cyclones (fig. 1).

In the past few years the performance of most of these cyclones has been satisfactory even though they were not perfect and allowed some visible dust to escape into the atmosphere. Because it was felt that these emissions were relatively unimportant, they caused little concern. However, adoption recently of more stringent air pollution control regulations by various local, State, and Federal agencies has placed increased emphasis on dust and fly-lint emissions from ginning operations. Questions have now been raised concerning the amounts and sizes of dust emissions from small-diameter cyclones. Very little information was available to answer these questions. Because of this and the increased emphasis being placed on air pollution across the Nation, a more thorough evaluation of small-diameter cyclone performance was needed.

During the 1966-67 ginning season, tests were conducted at the Southwestern Cotton Ginning Research Laboratory, Mesilla Park, N. Mex., to gain more information on the performance characteristics of the small-diameter cyclone operating within a range of normal ginning conditions. The specific

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Figure 1. Well designed group of small-diameter cyclones at a commercial gin.

objectives of this study were: (1) To determine if an overloaded condition exists at high trash input rates; (2) to determine the effect of varying the cyclone inlet air velocity on collection efficiency; (3) to investigate the influence of trash exit size on collection efficiency and to determine if the exit should be closed airtight or open; (4) to evaluate the effect of modifying the cyclone with an inlet vane, and inlet helix, an ion gun, and a skimmer on cyclone performance; and (5) to evaluate the effect of size distribution of incoming trash on the amount of dust discharged.

EXPERIMENTAL PROCEDURE

These tests were designed to evaluate and compare the performance of the small-diameter cyclone operating under a variety of conditions that can exist at present-day cotton gins. These tests investigated trash input rates, cyclone inlet air velocities, trash exit conditions, several devices that had shown promise of improving cyclone collection efficiency, and incoming trash of different sizes.

The test equipment used in this investigation is shown schematically in figure 2. The equipment included a fan-intake control valve, centrifugal fan, trash feeder and dropper, 30-inch-diameter cyclone, trash collection barrel, and a foam filter. The fan-intake control valve was on one end of a 24-foot long fan-intake duct to regulate the flow of air into the fan. A standard pitot tube in the inlet duct was used to measure the velocity of air entering the fan. By continuously monitoring the pitot tube reading and making the necessary control valve adjustments, the air volume entering the fan-cyclone system was closely controlled at the desired level.

The trash feeder consisted of two screw conveyors driven by a variable speed unit. A small 6-inch auger was used for low trash feed rates, and a 12-inch auger was used for high rates. The desired trash feed rate was obtained by proper selection of auger size and speed. The trash dropped through a vacuum dropper into a 12-inch-diameter pipe on the discharge side of the fan and was conveyed approximtely 40 feet to the 30-inch-diameter cyclone (fig. 3). A 55-gallon barrel placed under the cyclone was used to hold the trash that had been collected by the cyclone. The barrel of trash was weighed at the end of each test run, and this weight, along with the time required to feed the material, was used to calculate the trash input rate. Approximately 50 pounds of trash was collected during each test run.

The discharge air from the cyclone was passed through a foam filter pad to remove any dust that escaped with the discharge air. The 3/4-inch polyurethane foam filter pad was 30 inches by 40 inches and had a density of 2 pounds per cubic foot (fig. 4). The amount of dust escaping from the cyclone during the test was determined by weighing the foam filter pad at the beginning and at the end of each testing period. After each test the pad was thoroughly cleaned with a vacuum cleaner.

EXPERIMENTAL RESULTS

Trash Input Rate

The trash input rate into a single 30-inch-diameter cyclone was varied in one test from approximately 80 to 3,500 pounds of trash per hour, at a nominal inlet air velocity of 3,000 feet per minute; 3,000 feet per minute is the recommended design inlet air velocity for small-diameter cyclones used at cotton gins. Tests were also run at two other inlet air velocities - nominally 2,800 and 3,400 feet per minute. Trash input rates of approximately 400 to 4,000 pounds per hour were used for these velocities. The dust escaping from the cyclone under each test condition was collected and weighed to the nearest 0.1 gram, and from these data the collection efficiency was determined. Each test condition was replicated three times, and the averages of these replications are given in table 1.

The trash used in this series of tests was obtained from a commercial gin and from machine-stripped cotton grown in the Lovington, N. Mex., area. The approximate composition of this trash is given in table 2. The trash exit of the 30-inch-diameter cyclone was 7 1/2 inches in diameter. This size opening bridged at trash input rates of 3,500 pounds per hour and greater.

The collection efficiencies shown in table 1 are extremely high for all test conditions. They ranged from a low of 99.94 percent to a high of 99.97 percent. At first glance this difference would not appear to be very important. However, the overall collection efficiency is not always the best means of describing cyclone performance, especially when the material being collected consists of particles of widely varying sizes - as is the case with gin trash. A more meaningful measure of performance is obtained by expressing the dust emissions from the cyclone in terms of weight of dust lost from a

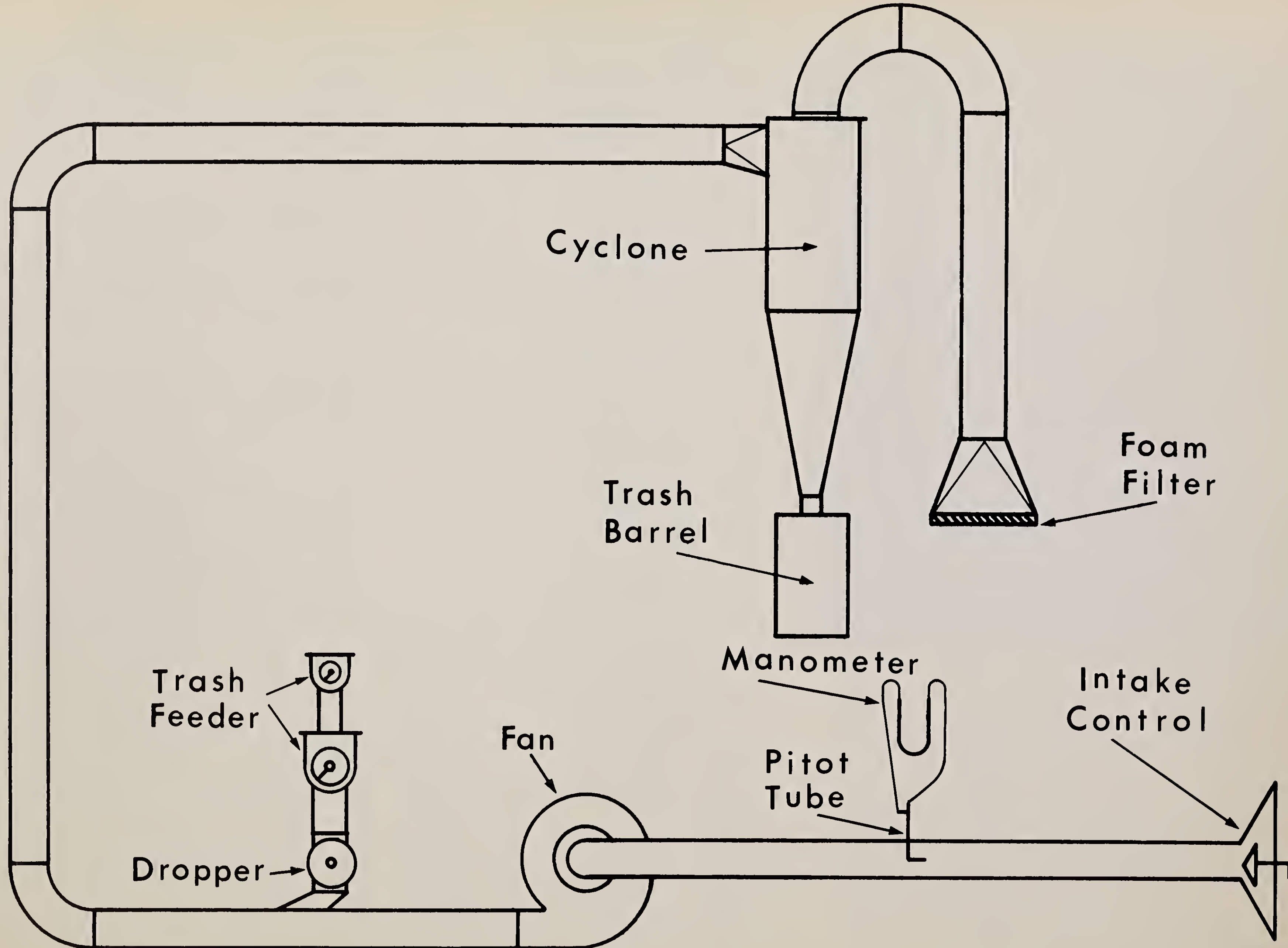
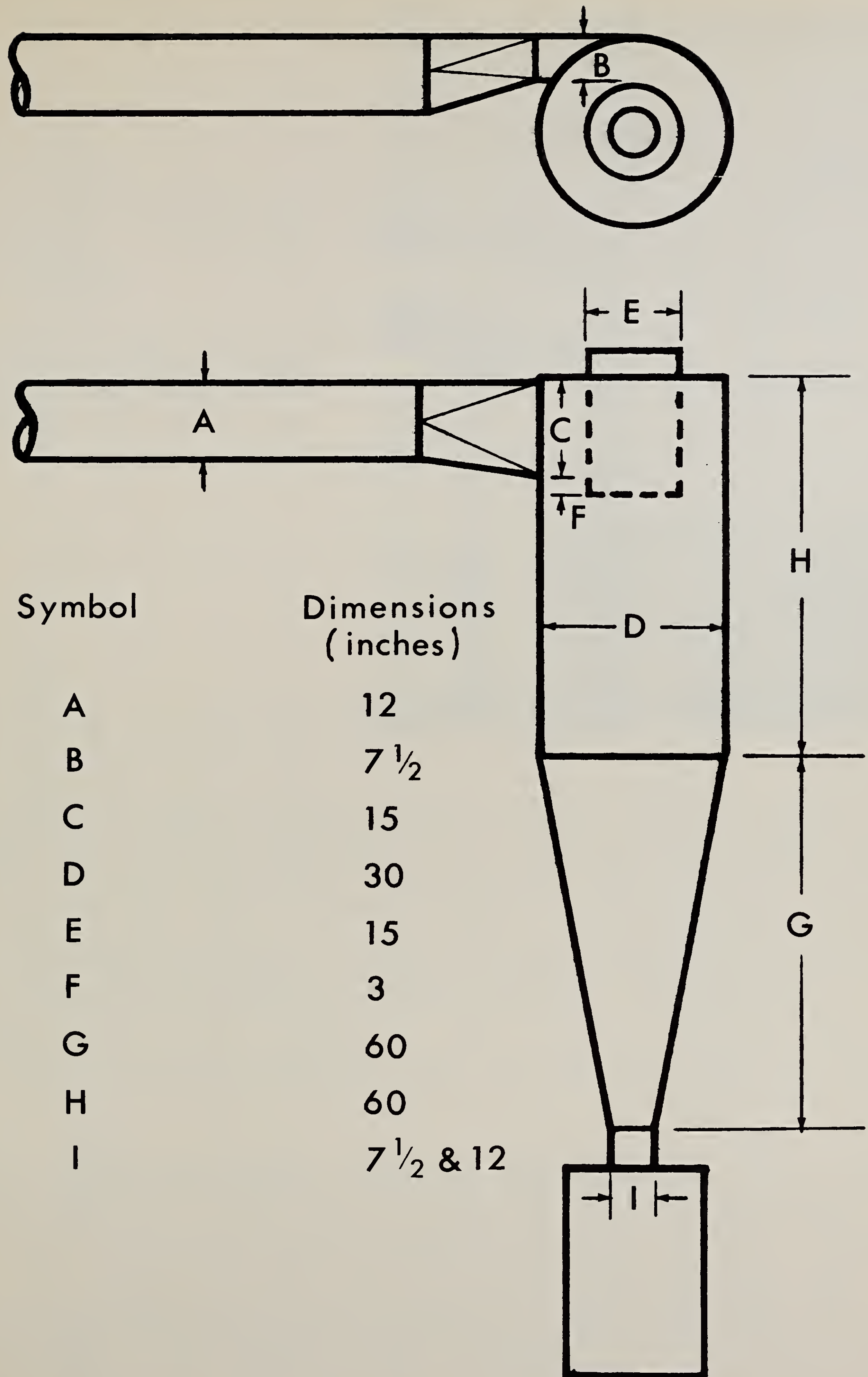


Figure 2. Schematic diagram of equipment used in cyclone tests.



Symbol	Dimensions (inches)
A	12
B	7 ½
C	15
D	30
E	15
F	3
G	60
H	60
I	7 ½ & 12

Figure 3. Dimensions of small-diameter cyclone used in this investigation.

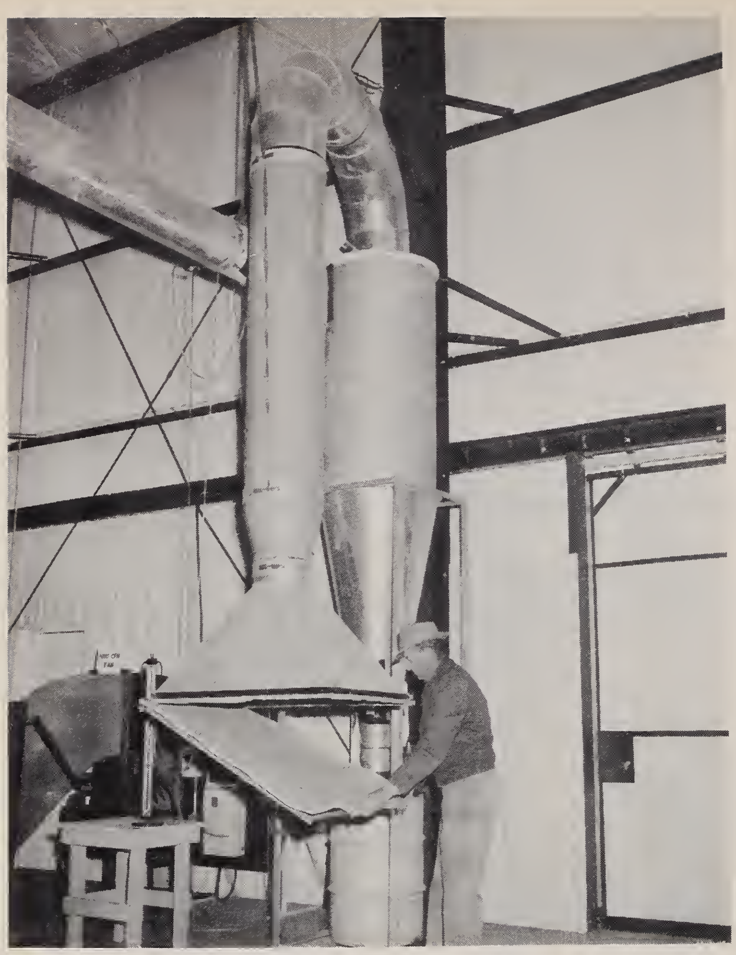


Figure 4. 30-inch-diameter cyclone, trash collection barrel, and foam filter pad used in this investigation.

given weight of trash. The fourth column in table 1 gives the grams of dust escaping from the cyclone for each 50 pounds of trash input to the cyclone, which varied from 12.5 to 8.6 grams when the trash input rate was increased from 84 to 2,447 pounds per hour (3,000-foot-per-minute inlet air velocity). Generally the same trend occurred at 2,800- and 3,440-foot-per-minute inlet air velocities. In all tests the cyclone performed most efficiently at the higher trash input rates as long as the trash exit opening did not bridge over. This contradicts the idea that cyclones at gins are being overloaded with too much trash. It appears that exactly the opposite was true in this case. That is, the effectiveness of the cyclone increased as the trash input rate increased, and this trend continued until the input rate became so great that the trash bridged at the cyclone trash exit.

The amount of dust escaping the cyclone per hour and the dust concentration in the exhaust air were calculated for each test condition (table 1). This information shows that the amount of dust lost in a given period of time depended to a large degree upon the amount of trash fed into the cyclone. The higher the trash input rate to the cyclone the greater the dust emission rate. This was true even though the cyclone operated slightly more efficiently at the higher input rates. This points out the importance of considering both collection efficiency and trash input rate when evaluating overall cyclone performance. Statistically, at the 5-percent level, the number of grams of dust lost per 50 pounds of trash input was significantly higher at

Table 1. Stripper trash input rate test results

Trash input rate	Inlet air velocity 1/	Cyclone collection efficiency 2/	Dust escaping from cyclone per 50 pounds trash input 3/	Dust escaping from cyclone per hour	Average dust concentration in exhaust air
Pounds per hour	Feet per minute	Percent	Grams	Grams	Micrograms per cubic meter
84	2,960	99.94	12.5	21	5,320
209	2,960	99.95	11.2	47	11,900
344	2,960	99.96	9.0	62	15,650
412	3,170	99.95	10.3	85	20,100
986	3,160	99.97	7.8	154	36,400
2,447	3,080	99.96	8.6	422	102,500
3,427 4/	3,130	-----	11.0 4/	---	----
407	2,850	99.96	8.9	72	19,100
1,045	2,830	99.96	8.0	167	44,200
2,150	2,820	99.97	6.7	288	76,500
4,346 4/	2,810	-----	9.6 4/	---	----
417	3,480	99.95	11.8	98	20,600
925	3,420	99.96	8.3	154	33,700
2,030	3,420	99.96	8.9	362	79,500
4,010 4/	3,440	-----	10.1 4/	---	----

1/ Inlet air density = 0.064 to 0.069 pounds per cubic foot.
2/ Based on total trash weight collected and dust weight lost.
3/ Average of three replications.
4/ Cyclone trash exit bridged at this rate; trash exit was 7 1/2 inches in diameter.

Table 2. Size composition of two types of gin trash used in this investigation

Size range (microns)	Stripper trash	Picker trash
	Percent by weight	Percent by weight
Larger than 3,300---	67.5	49.8
420 - 3,300---------	27.2	42.3
74 - 420------------	4.5	5.7
Smaller than 74-----	0.8	2.2
Total---------	100.0	100.0

the low input rates than at the high input rates. This was the case for all groups of data obtained in this test series as long as the cyclone trash exit did not choke.

Inlet Air Velocity

In one test the cyclone inlet air velocity (table 3) was varied from 2,130 to 4,750 feet per minute at a constant trash input rate of 1,300 pounds per hour, using rough trash from machine-stripped cotton. Another test was also run using trash from machine-picked cotton. This picker trash was fed into the cyclone at 90 pounds per hour and at inlet air velocities of 2,130, 2,960, and 4,750 feet per minute. The approximate composition of both the picker trash and stripper trash is given in table 2. The 30-inch-diameter cyclone used for these tests had a 7 1/2-inch-diameter trash exit.

Each test condition was replicated four times, and the averages of these replications are given in table 3. The amount of dust escaping per 50 pounds of picker trash input was lowest at the 2,130-foot-per-minute inlet air velocity and increased as the inlet air velocity was increased. These data show that for both types of trash the collection efficiency was highest at an inlet air velocity of approximately 2,150 feet per minute and decreased to its lowest value at the 4,750-foot-per-minute inlet air velocity. Figure 5 shows how various inlet air velocities affect dust emissions from cyclones. The pressure drop of the cyclone at the various inlet air velocities is given in figure 6.

The centrifugal force acting upon a particle within the cyclone increases as the inlet air velocity increases. It is generally assumed that higher centrifugal forces will produce higher collection efficiencies. However, in this test this was not the case. Visual observations made during the test help to explain this deviation from the theoretical.

Table 3. Inlet air velocity test results

Type of trash and inlet air velocity 1/	Trash input rate	Cyclone collection efficiency 2/	Dust escaping from cyclone per 50 pounds trash input 3/	Dust escaping from cyclone per hour	Average dust concentration in exhaust air
Feet per minute	Pounds per hour	Percent	Grams	Grams	Micrograms per cubic meter
Stripper trash:					
2,150	1,320	99.96	9.1	240	83,800
2,660	1,400	99.96	9.6	269	75,900
3,170	1,260	99.95	10.2	257	60,800
3,720	1,400	99.94	13.2	370	74,600
4,240	1,370	99.93	15.9	437	76,900
4,750	1,380	99.91	19.8	548	86,400
Picker trash:					
2,130	91	99.94	14.5	26	9,300
2,960	90	99.92	18.5	33	8,500
4,750	90	99.78	48.8	88	13,900

1/ Inlet air density = 0.066 pounds per cubic foot.
2/ Based on total trash weight collected and dust weight lost.
3/ Average of four replications.

Action occurring within the cyclone was observed through windows in the top of the cyclone. Movies were also taken for further study. A great deal of turbulence existed within the cyclone at the higher inlet air velocities. Much of this turbulence was caused by obstructions on the interior surface of the cyclone. Bolt heads, sheet-metal seams, and other protruding objects interfered with the normal flow pattern of the trash spiralling downward around the circumference of the cyclone. The trash particles that impacted with these obstructions were deflected from the cyclone wall. Many were deflected to the extent that they entered the inner vortex of upward moving air and were carried out the top of the cyclone. The distance the particles were deflected depended upon their velocity at the time of impact. At the higher velocities particles were deflected farther than at the lower veloc-

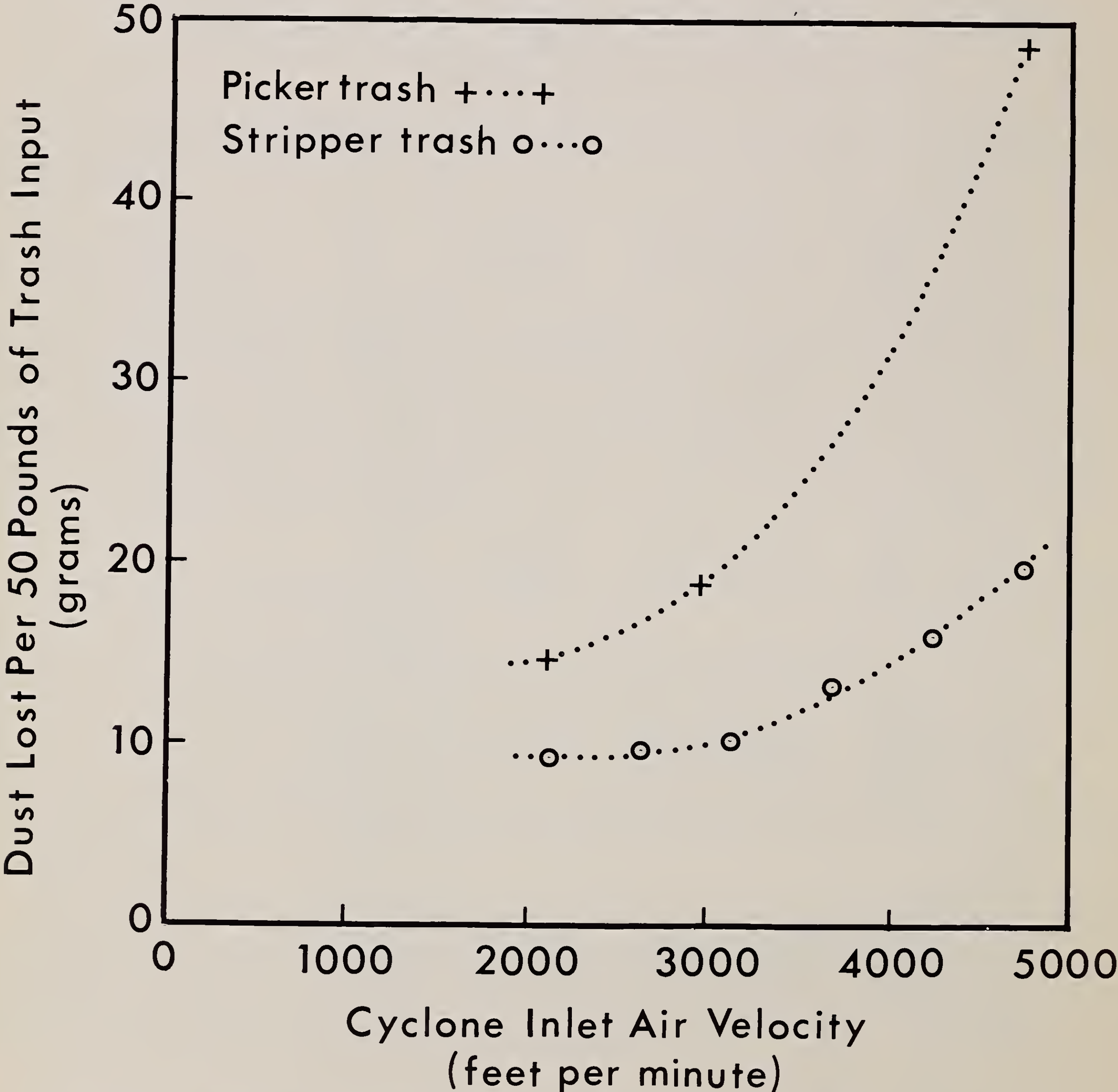


Figure 5. Effect of inlet air velocity on cyclone dust emissions.

ities. Consequently, more particles were lost in this manner at the high inlet velocities. Also, much more turbulence occurred at the bottom of the cone at high inlet air velocities. This turbulence prevented dust from leaving the cyclone and contributed to the increased dust losses.

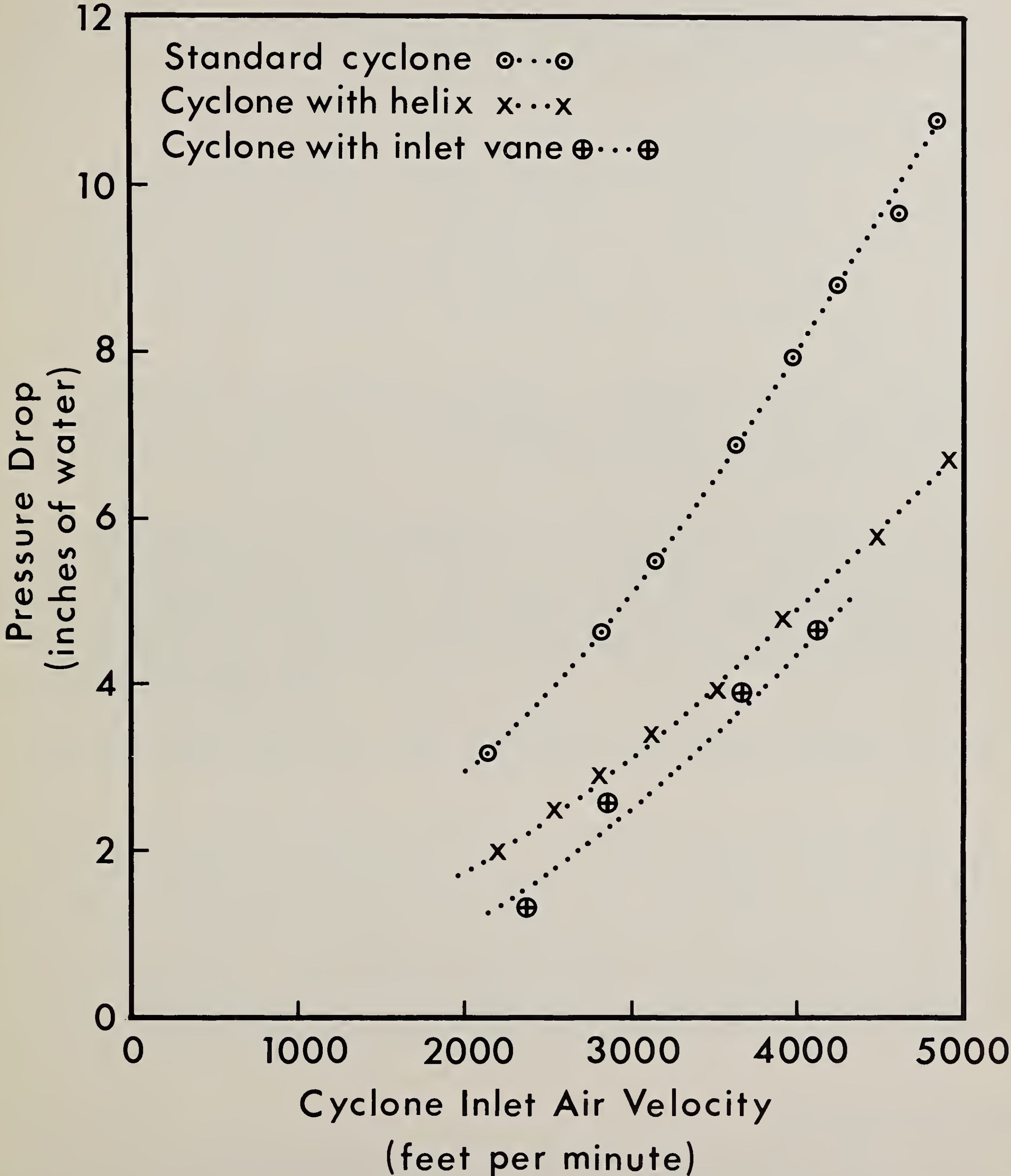


Figure 6. Pressure drop characteristics of a standard, unmodified 30-inch-diameter cyclone, a cyclone with a helix, and a cyclone with an inlet vane.

At the 5-percent level of significance the dust losses at the high inlet velocities, above 3,170 feet per minute, were significantly higher than the dust losses at inlet velocities below 3,170 feet per minute. This occurred at both the 1,300-pound-per-hour stripper trash input rate and at the 90-pound-per-hour picker trash input rate.

The dust concentration in the exhaust air depended upon the dust emission rate and the volume of air passing through the cyclone. In these tests the average dust concentration in the exhaust air was lowest for inlet air velocities near 3,000 feet per minute.

Trash Exit Investigations

Tests were run to determine the effect of an airtight seal and open trash discharge on cyclone collection efficiency. For one test the trash barrel was sealed airtight, and for the other a 4-inch-diameter hole was opened in the barrel top to allow air to leak out. Picker trash (see table 2) was fed into the cyclone at a rate of 1,300 pounds per hour, and an inlet air velocity of 3,000 feet per minute was used. Each condition was replicated three times.

The amount of dust escaping the cyclone averaged 19.3 grams per 50 pounds trash input for the airtight condition and 17.5 grams for the open condition. Statistically, the difference in these two averages was not significant at the 5-percent level.

Visual observations were made by five people when the cyclone was operated under these two conditions. In this case the cyclone exhaust air was allowed to discharge straight out the top of the cyclone, and the observers judged the amount of dust discharged under each condition. Two of the five observed more dust discharging from the cyclone when it was operating under the airtight condition. Three of the five observed no difference between the two test conditions. Visual observations have definite limitations, but these observations did illustrate that any differences that may have existed between the two test conditions were very small and not significant.

A 30-inch-diameter cyclone with a 12-inch-diameter trash exit was tested, and the results were compared with the results obtained from tests using a 7 1/2-inch-diameter trash exit. No differences in collection efficiency were noted for these two sizes of trash exits. The 12-inch trash exit could handle larger volumes of trash without bridging than could the 7 1/2-inch exit. However, because equipment was limited, the maximum volume of trash that the 12-inch exit could handle could not be determined. In previous tests the 7 1/2-inch trash exit bridged at trash input rates above 3,500 pounds per hour.

Cyclone Modifications

Several modifications were made on the small-diameter cyclone in attempts to improve its performance (fig. 7). Four devices, an inlet vane, helix, an ion gun, and a skimmer, were tested, and the results from each test were compared with the performance of an unmodified cyclone.

The inlet vane was a flat sheet-metal plate, which was placed on the inner side of the cyclone inlet duct and extended from the cyclone wall across the annular space to the air outlet duct. The inlet vane reduced the pressure drop through the cyclone about 60 percent (fig. 6). Unfortunately, it also reduced the cyclone collection efficiency. About three times more material was emitted from the cyclone with the inlet vane than from the unmodified cyclone.

A cyclone with an inlet helix was tried next. The flat top of the cyclone was spiralled downward from a point at the top of the air inlet extending one revolution around the cyclone and ending at the bottom of the air inlet. This arrangement directed the incoming trash and air downward in a spiral, thus reducing interference of the incoming air with that already spiralling inside the body of the cyclone. This cyclone with the inlet helix performed similarly to the one having a flat inlet vane. Both the pressure drop and efficiency were reduced when the inlet helix was used. About two and one-half to three times more material was lost from the cyclone with the inlet helix than from the unmodified cyclone.

An ion gun that could produce negative ions in an airstream was placed in the inlet transition. A stainless-steel needle electrode and a brass plate were the principal components of the gun. The needle electrode was placed close to a small, round orifice in the brass plate. A high-voltage power supply imposed a 7,000-volt d.c. electrical potential across the needle electrode and the brass plate. The brass plate was positively charged. Air from a 50-p.s.i. compressed air source was passed by the needle electrode and forced through the orifice into the cyclone inlet airstream. This arrangement caused a corona discharge at the electrode, thereby producing negative ions in the airstream. It was anticipated that the ions would encourage agglomeration of small dust particles into larger units that could be collected more efficiently. Tests were conducted with and without the ion gun, and it was found that the negative ions did not significantly affect the collection efficiency.

During previous cyclone tests a thin band of dust approximately 2-inches wide and 1/8-inch thick revolved continuously around the top of the cylinder of the cyclone. The density of the band of dust reached an equilibrium soon after the cyclone began operation and remained relatively stable as long as trash was entering the cyclone. This dust band may have been influencing the amount of dust being lost out the top of the cyclone. For this reason, a skimmer was placed in top of the cyclone to remove this dust band. The skimmer was a 1 1/2-inch circular conduit placed in the top of the cyclone near its outer edge. The skimmer removed substantial quantities of dust and practically eliminated the band of dust. However, it did not significantly affect collection efficiency. Evidently the band of dust was not influencing the volume of dust being lost from the cyclone.

Size of Trash

The amount of dust discharged from the cyclone depended upon the size distribution of the incoming trash. Two types of gin trash were used in these investigations. The size composition, as determined by sieve analysis,

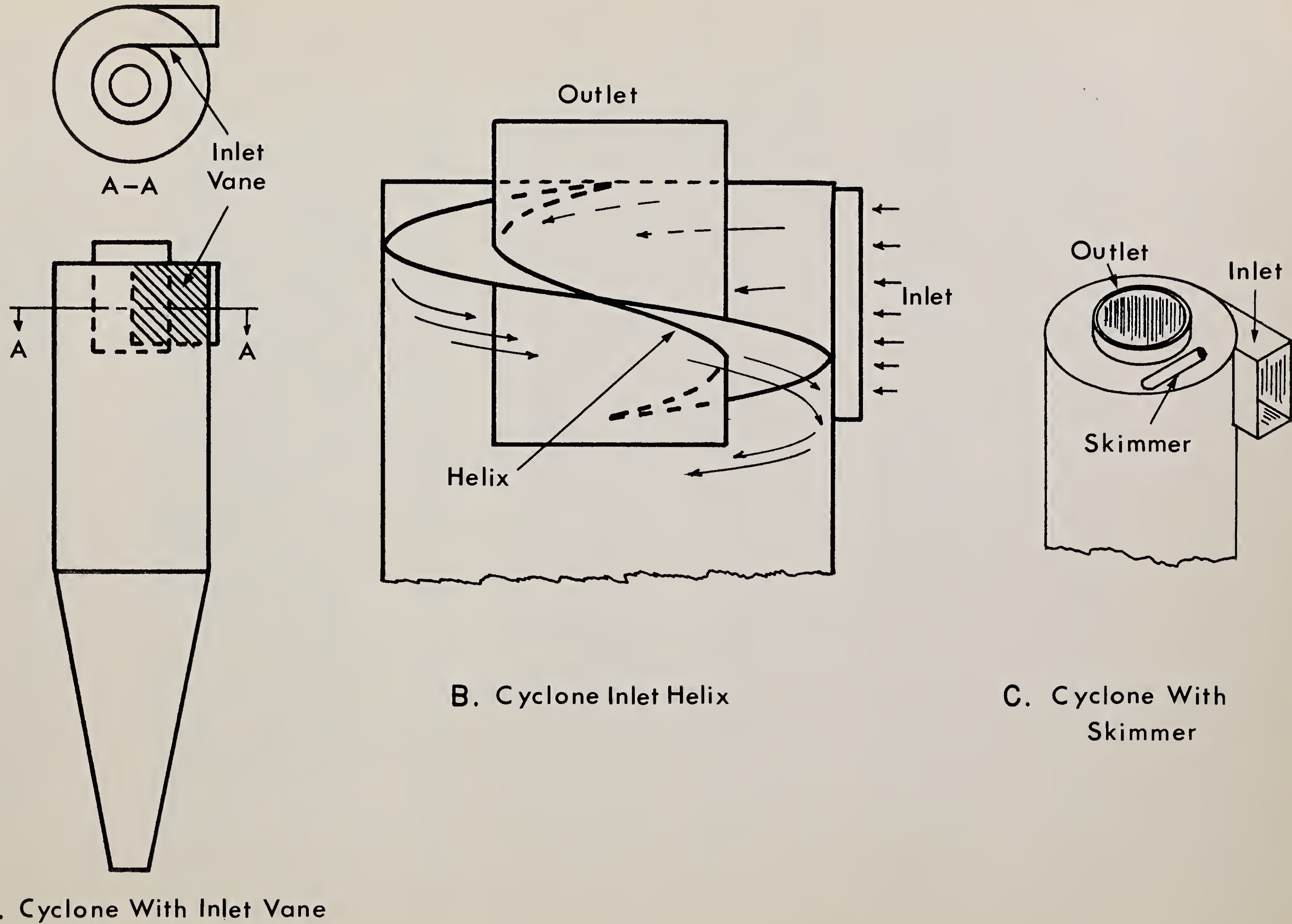


Figure 7. Cyclone modifications (A) Inlet vane, (B) Helix, and (C) Skimmer.

of the two types of trash is given in table 2. The stripper trash was much coarser than the picker trash and contained fewer particles smaller than 74 microns in diameter. For this reason, the stripper trash was easier to collect and cyclone collection efficiencies were higher.

Microscopic examination of the dust that had escaped the cyclone showed that most of it was smaller than 50 microns in diameter, and a great deal of it ranged from 1 to 10 microns. Very little lint fibers escaped the cyclone, although the input trash contained a great deal of fibrous material. The cyclone collected virtually all the particles larger than 50 microns. Particles smaller than 50 microns were partly collected in decreasing amounts as they became smaller. Therefore, the amount of dust lost from the cyclone depended upon the amount of dust in the incoming trash that was amaller than 50 microns in diameter. Sieve analysis test results showed that the cyclone collected an estimated 90 to 95 percent of the dust in the trash smaller than 50 microns.

The collection efficiency of the cyclone was also measured when other types of materials were collected. Cyclone efficiency was 99.1 to 99.6 percent in collecting condenser exhaust material. This material was approximately 50 percent cotton fibers shorter than 1/4 inch, 25 percent trash particles larger than 265 microns, and 25 percent particles smaller than 265 microns. The material that escaped the cyclone under these conditions was fine dust and lint fibers. A good percentage of the cyclone emission was lint fibers.

Vacuum-cleaner dust was fed into the cyclone at a rate of 1 3/4 pounds per minute with an inlet air velocity of 3,000 feet per minute. This very fine dust consisted mainly of particles smaller than 50 microns. Cyclone efficiency was 97.6 percent in collecting this material.

SUMMARY AND CONCLUSIONS

The small-diameter cyclone very efficiently collects trash from cotton ginning operations. Tests at the Southwestern Cotton Ginning Research Laboratory, Mesilla Park, N. Mex., have shown that the small-diameter cyclone will maintain collection efficiencies of 99.9 percent and greater over a wide range of operating conditions and gin trash sizes.

These tests showed that several factors affected cyclone performance. Trash input rates, inlet air velocities, and the size distribution of the trash all influenced the operation of the cyclone.

The collection efficiency of the cyclone increased slightly as the trash input rate was increased from approximately 80 to 3,500 pounds per hour. This trend continued until the input rate became large enough to cause trash to bridge at the cyclone trash exit. A 30-inch-diameter cyclone with a 7 1/2-inch-diameter trash exit bridged at an input rate of 3,500 pounds per hour.

The cyclone inlet air velocity was varied from 2,130 to 4,750 feet per minute at trash input rates of 90 and 1,300 pounds per hour. Under these conditions the collection efficiency decreased as the inlet air velocity

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increased. Over twice as much dust was emitted from the cyclone at the 4,750-foot-per-minute inlet velocity than was emitted at the 2,130-foot-per-minute velocity. Turbulence caused by obstructions inside the cyclone at the higher velocities appeared to be the primary reason for this. At inlet velocities below 3,000 feet per minute collection efficiency changed little. Most of the reductions in efficiency were at the inlet velocities of more than 3,000 feet per minute.

Tests also showed that there was little difference in collection efficiency between a trash exit discharging into an airtight container and an exit discharging into an open container. Two sizes of cyclone trash exits were tested to determine the influence of exit size on collection efficiency. A 7 1/2-inch-diameter and a 12-inch-diameter exit were tested on a 30-inch-diameter cyclone. There was no difference in collection efficiency between the two sizes, but the 12-inch size could handle larger volumes of trash without bridging.

An inlet vane, an inlet helix, an ion gun, and a skimmer were tested to determine their effect on cyclone performance. The inlet vane and inlet helix substantially reduced cyclone pressure drop but also reduced collection efficiency. The ion gun and skimmer did not affect either pressure drop or efficiency.

The small-diameter cyclone collected stripper trash slightly more efficiently than picker trash because the stripper trash contained a lower percentage of small dust particles. The cyclone collected virtually 100 percent of the trash particles larger than 50 microns in diameter. The particles smaller than 50 microns were partly collected in varying degrees, depending upon their diameter. The percentage of smaller particles collected decreased as the particle diameter decreased. Cyclone collection efficiency was 99.1 to 99.6 percent for condenser exhaust material and 97.6 percent for vacuum-cleaner dust.